Distribution of Plecoptera, Ephemeroptera and Trichoptera in a stream system in Øvre Heimdalen, Jotunheimen Mountains, in relation to environmental variables.

Utbredelse av steinfluer, døgnfluer og vårfluer i rennende vann i Øvre Heimdalen, Jotunheimen i forhold til miljøvariabler.

Nina Kristine Stein Helland

Norwegian University of Life Sciences
Department of Ecology and Natural Resource Managment

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Preface

This is my master`s thesis in natural resource management at the Institute of Ecology and Natural Resource Management (INA) at the University of Life Sciences (UMB).

I would like to thank my supervisor John E. Brittain (INA) for his help with my fieldwork and constructive comments during the thesis writing. Thanks are also due to Bjørn Walseng at the Norwegian Institute for Nature Research (NINA), for his help with the ordination analysis, Knut Asbjørn Solhaug (INA) for his help with the Chlorophyll *a* analysis and Annie Aasen (INA) for facilitation at the laboratory.

Thanks to the Natural History Museum at University of Oslo for letting me use their facilities at the field station in Øvre Heimdalen. Thanks to the Norwegian Water Resources & Energy Directorate (NVE) for lending me digital temperature loggers.

A special thanks to my dear friend Siri Berger for help with my fieldwork, advice during the process and proof-reading the final week. Also thanks to my brother Kay-Arne S. Helland for helping me in field. Thanks to Hege, Ola, Petter and my friends for believing in me and helping me keep my spirit. At last, but not least, I would thank Bjørn Grønvold for his support, both emotional and economical, making it possible for me to write this thesis.

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Nina Kristine Stein Helland

Abstract

The present study focus on the distribution of Plecoptera, Ephemeroptera and Trichoptera in an alpine stream system, related to environmental variables. The study was conducted in the valley Øvre Heimdalen situated in the Jotunheimen Mountains. Field surveys were performed in six reaches situated in an altitudinal gradient from 1085 to 1351 m a.s.l. Invertebrate sampling was performed in June, July and September 2009. Ten environmental variables were recorded during the season.

A total of 31 species was identified, whereas the species *Hydroptila* sp. had no former records in the area. The ephemeropteran *Bäetis rhodani* dominated all reaches, except the outlet of Øvre Heimdalsvatn, where the trichopteran filter feeder *Polycentropus flavomaculatus* was recorded in high numbers. Collectors were the dominant feeding group in the outlet of Øvre Heimdalsvatn, while scrapers (grazer) dominated the other reaches.

The Detrended Correspondence Analysis (DCA) did not show a clear altitudinal gradient in the stream system investigated, but the linear regression showed a decrease in number of species with increasing altitude. A change in species composition from the inlet of Brurskardtjern to Brurskardbekken and further a change in species composition from Brurskardbekken and to the outlet of Øvre Heimdalsvatn were detected.

The main explanatory environmental variables in this study were discharge, substratum size and temperature. The percentage amount of particular organic matter and levels of chlorophyll *a,* had intermediate influence on the distribution pattern, while environmental variables related to channel stability (depth, current velocity and the Pfankuch index), explained little relationship to the pattern of variation in species distribution.

The Canonical Correspondence Analysis (CCA) clearly separated the outlet of Øvre Heimdalsvatn from the other stream sites situated in Brurskardbekken and the inlet stream of Brurskardtjern. This indicates that the difference in stream invertebrate fauna between alpine streams and lake outlets is the main explanation for the results in this study.

Sammendrag

Denne studien fokuserer på utbredelsen av steinfluer, døgnfluer og vårfluer i rennende vann i et alpint fjellområde i forhold til miljøvariabler. Studien ble gjennomført i Øvre Heimdalen som ligger i Jotunheimen. Feltundersøkelser ble gjort på seks stasjoner i en høydegradient fra 1085 til 1351 moh. Innsamling av evertebrater ble gjennomført i juni, juli og september 2009. Ti ulike miljøvariabler ble registrert i løpet av sesongen.

Det ble totalt identifisert 31 arter, hvorav arten *Hydroptila* sp. ikke har blitt registrert i området tidligere. Døgnfluen *Bäetis rhodani* dominerte alle stasjoner, bortsett fra utløpet til Øvre Heimdalsvatn, hvor et høyt antall av vårfluen *Polycentropus flavomaculatus* ble registrert. Samlere var den dominerende fødeopptaksgruppen i utløpet til Øvre Heimdalsvatn, mens påvekstetere dominerte de resterende stasjonene.

Detrended Correspondence Analysis (DCA) viste ikke noen klar høydegradient i det undersøkte elvesystemet, men lineær regresjon viste en nedgang i antall arter ved økende høyde over havet. Det ble påvist en endring i artssammensetningen fra innløpet til Brurskardtjern og til Brurskardbekken, og videre en endring fra Brurskardbekken og til utløpet av Øvre Heimdalsvatn.

Vannføring, størrelse på bunnsubstrat og temperatur var de miljøvariablene som forklarte mest i dette studiet. Prosentandel organisk materiale og mengde klorofyll *a* hadde middels innflytelse på utbredelsesmønsteret, mens miljøvariabler knyttet til stabilitet (dybde, strømhastighet og Pfankuch indeks) forklarte lite av variasjonen i forhold til artenes utbredelsesmønster.

Utløpet fra Øvre Heimdalsvatn ble i ordinasjonsanalysen tydelig separert fra de andre stasjonene i studiet. Dette indikerer at forskjeller i evertebratfauna mellom alpine elver og utløp fra innsjøer er hovedforklaringen på resultatene i denne studien.

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1. Introduction

The decline in species richness with increasing elevation and altitude is widely accepted as a general pattern in biology (Rahbek 1995), but there have been few studies including aquatic organisms. The freshwater environment is fundamentally different from the terrestrial, and could contribute valuable information on richness patterns and important environmental factors (Jacobsen 2004). It is likely that rivers will be among the most sensitive of all ecosystems to climate change (Ormerod 2009). Scientific knowledge about freshwater invertebrates is limited (Strayer 2006), and it is necessary to improve the understanding of the diversity, distribution and conservation requirement of such species, especially in mountain areas (Brown et al. 2009).

Alpine streams are characterised by short growing seasons, cold turbulent water and low availability of nutrients and organic matter (Hieber et al. 2002), providing a harsh environment for species inhabiting these areas. A range of environmental variables may dynamically shape the characteristics of alpine streams, producing a variety of habitats within which benthic communities exists (Brown et al. 2003). Some characteristics such as elevation, thermal regime, and stream size change relatively predictably along undisturbed stream gradients and sequentially alter benthic community structure (Grubaugh et al. 1996; Vannote et al. 1980). Other characteristics such as streambed slope, substratum composition, and current velocity often change more locally and with less predictability (Statzner & Higler 1986).

Water temperature has long been recognised as a major contributor to stream community structure and functions (Hynes 1970; Vannote et al. 1980; Ward 1985). Channel stability has been considered, in addition to temperature, to be the most important environmental factor influencing zonation of benthic distribution in glacier fed streams (Milner & Petts 1994). The substratum is a key control on channel and bed stability (Pfankuch 1975). Invertebrates ability to adhere, cling, burrow and build cases are directly influenced by the characteristics of the substratum, and indirectly the substratum affect the composition of benthic communities trough the direction, force and turbulence of water flows (Brown et al. 2003).

Inputs of allochthonous organic matter to streams act as an important energy source for benthic macroinvertebrates (Cummins et al. 1973) and can influence their distribution and abundance (Vannote et al. 1980). Epilithic algae may be an essential food source for macroinvertebrates occupying alpine streams, due to low levels of allochthonous matter inputs above the tree line (Fuller et al. 1986; Rott et al. 2006).

Stoneflies (Plecoptera), mayflies (Ephemeroptera) and caddisflies (Trichoptera) are important groups in Norwegian freshwater systems, represented with 35, 45 and 195 species, respectively (Aagaard et al. 2002; Sundby 1995). Many Plecoptera, Ephemeroptera and Trichoptera demonstrate flexible life cycles, allowing them to inhibit a wide range of climates and habitats (Reiso & Brittain 2000 a; Sand 1997). Based on their feeding habits, Ephemeroptera and Plecoptera nymphs and Trichoptera larvae can be grouped into the following categories: Shredders, collectors, scrapers (grazers), piercers and predators (Solem & Gullefors 1996). Many species do not strictly belong to one functional feeding group, but in most cases one can assign them to the group where they obtain their main food (Lillehammer & Brittain 1978). Scrapers (grazers) usually dominate in the treeless alpine region in Norway (Aagaard et al. 2004).

There have only been a few studies of species compositions of freshwater invertebrates in high mountain streams in Norway (Aagaard et al. 2004; Lillehammer & Brittain 1978; Raddum & Fjellheim 2002). Lillehammer & Brittain (1978) documented the Ephemeroptera, Plecoptera and Trichoptera fauna in Øvre Heimdalen. The distribution and biology of Trichoptera species in Øvre Heimdalen have been further investigated by Reiso (1999) and Reiso & Brittain (2000a; 2000b). Several studies on Plecoptera species (Brittain 1983; Sand & Brittain 2009) and Ephemeroptera species (Brittain 1978; Sand 1997; Sand & Brittain 2009) have also been conducted.

Several papers have dealt with environmental variables influencing the insect composition in Alpine streams (Brown et al. 2003; Füreder et al. 2002; Hieber et al. 2005). Few analyses of faunal composition in relation to environmental variables have been made in Norwegian mountain streams, except from a few glacial streams (Brittain et al. 2001).

The main objectives in this study were to document the distribution patterns of Plecoptera, Trichoptera and Ephemeroptera inhabiting an altitudinal gradient in Øvre Heimdalen, and using multivariate techniques to determine which environmental variables influenced the distribution pattern.

2. Study area

2.2. Øvre Heimdalen

This study was carried out in Øvre Heimdalen valley, situated on the eastern slopes of the Jotunheimen Mountains on the border between Øystre Slidre and Vågå municipality in central Norway. The aquatic insect fauna was investigated in six reaches; one in the inflow stream to Brurskardtjern, four in Brurskardbekken and one in the outflow of Øvre Heimdalsvatn (Fig. 1).

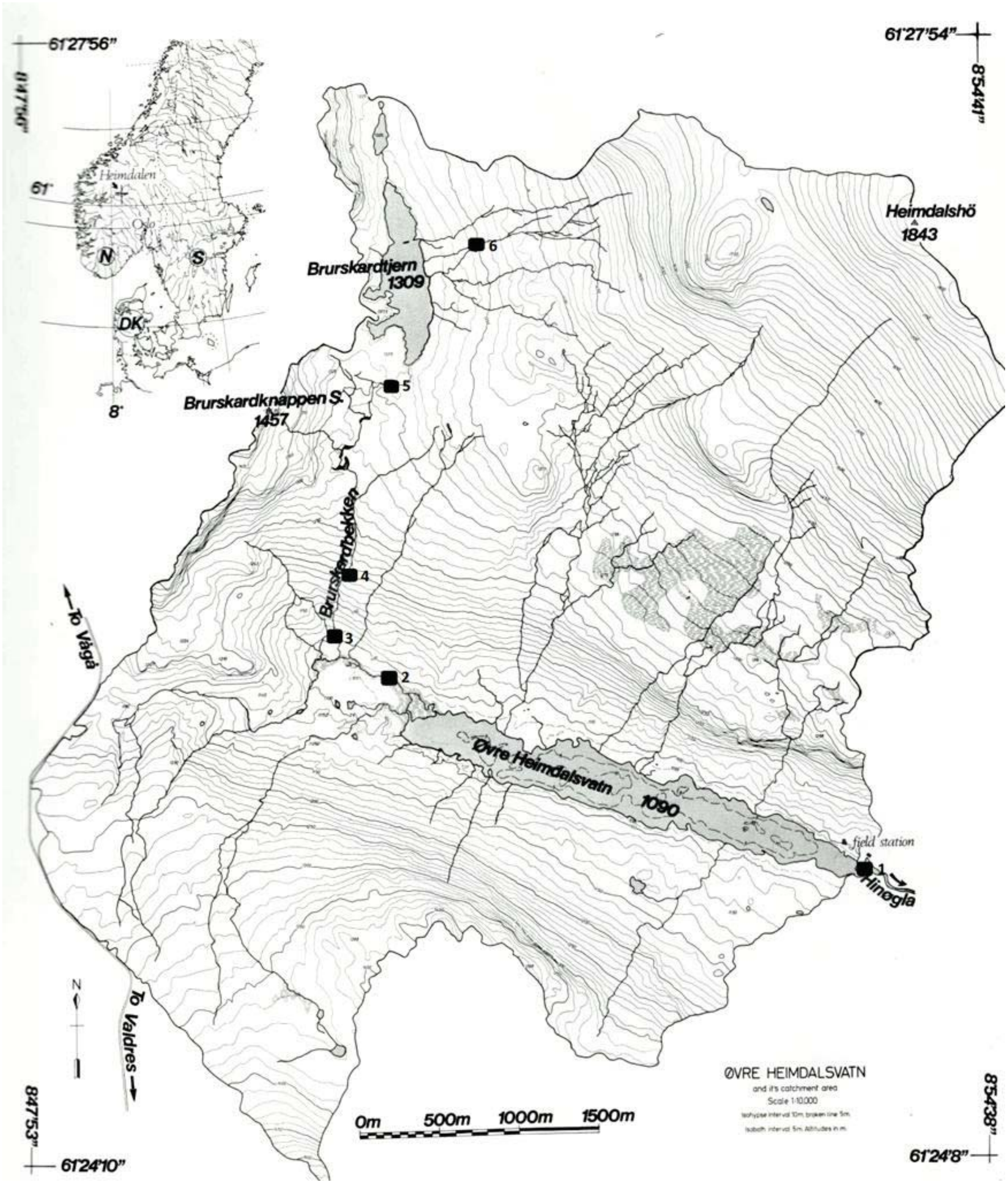

Figure 1. Map of the Øvre Heimdalen valley, altitudes in m a.s.l. (Vik 1978). Stations 1 to 6 are marked

Small streams rise at the western slopes of Heimdalshøe (1843 m a.s.l.) and flow into the small lake Brurskardtjern situated at an altitude of 1309 m a.s.l. Brurskardbekken flows out of the lake and falls gradually until 1275 m a.s.l., where it flows through a series of small ponds. After 1250 m a.s.l. the gradient increases substantially until the stream reaches the valley floor at 1100 m a.s.l. From Brurskardtjern, the stream flows 3.2 km before entering the lake, Øvre Heimdalsvatn, at 1090 m a.s.l. (Reiso & Brittain 2000 a). Øvre Heimdalsvatn is 3 km long and 400 m wide. The outlet stream, Hinøgla, flows out eastward from Øvre Heimdalsvatn (Fig. 1).

The bedrock in Øvre Heimdalen, consists mostly of basic Precambrian rocks, which are a part of the large Caledonian thrust complex "Jotundekkene" (Skjeseth & Kloster 1978).

The dominating vegetation types in the study area include mountain birch forest, bilberry heath, mire vegetation, chionophobous heath vegetation and snowbed communities. The timber line is approximately at 1200 m a.s.l. (Østhagen & Egelie 1978).

Øvre Heimdalen is situated in a mountain area with subarctic or tundra macroclimate. The favorable combination of slope angle and exposure of the NNE side of the valley, were Brurskardbekken runs, gives this area a continental local climate. This results in higher air temperatures, greater precipitation and higher air humidity than elsewhere in the valley. (Johannessen 1978). Winters in Øvre Heimdalen are long and the lake Øvre Heimdalsvatn is ice covered from late October until the beginning of June (Kvambekk & Melvold 2010).

Water temperatures recorded during 2008/2009 in the outlet of Øvre Heimdalsvatn, showed temperatures just above 0°C from late October until May and then a rapid increase in temperatures after ice break, reaching 18°C in early July. Water temperatures began gradually to fall in late August (Fig. 2).

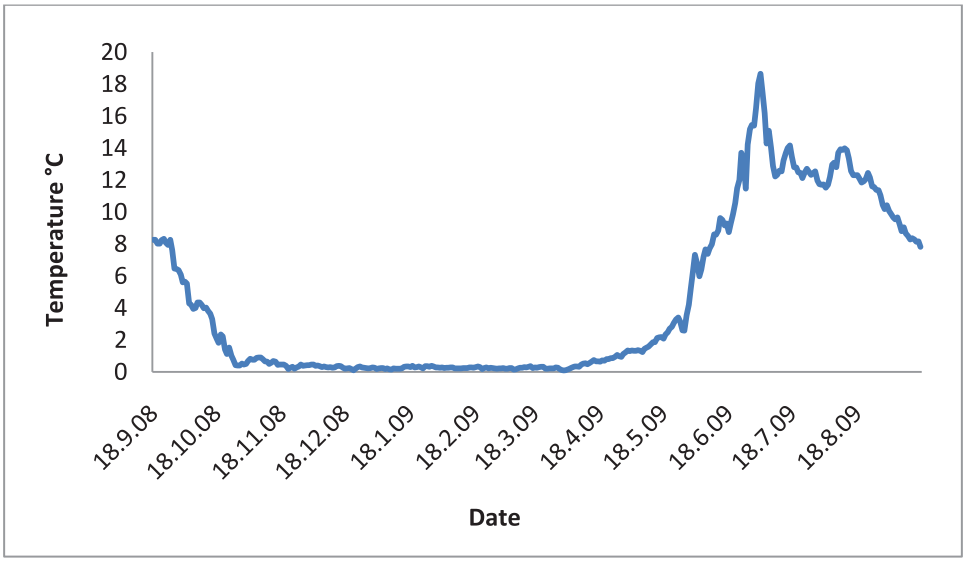

Figure 2. Mean daily water temperatures (°C) in the outlet of Øvre Heimdalsvatn during 2008/2009

2.2. Description of sampling reaches

Station 1 (UTM32N, 6809321 N, 494504 E) is located at 1085 m a.s.l. in the stream Hinøgla, in the outlet of Øvre Heimdalsvatn. The stream is 19 m wide, before it splits in two streams, respectively 3 and 13 m. The substrate consists of a mixture of large and medium sized boulders and some coarse gravel, covered with mosses and detritus. The surrounding vegetation is dominated by bilberry heath, willow thickets and scattered birch trees (Fig. 3a).

Station 2 (UTM32N, 6810601 N, 491444 E) is located at 1092 m a.s.l in the stream Brurskardbekken, a few hundred meters from the inflow into the lake Øvre Heimdalsvatn. The stream is about 4 m wide and splits for a few meters into two smaller streams. The substrate is dominated by fine gravels, coarse gravels and some sand. The flora in the area is mainly mire vegetation, some birch trees and willow thickets (Fig. 3b).

Station 3 (UTM32N, 6810937 N, 491092 E) is located at 1116 m a.s.l in dense subalpine birch forest. The stream is about 4 meters wide and the substrate is dominated by coarse gravels and some large boulders with some algae and allochthonous organic material. The vegetation is richer than the other stations and includes tall herbs and ferns, together with bilberry heath (Fig. 3c).

Station 4 (UTM32N, 6811259 N, 491191 E) is situated just above the timber line at 1200 m a.s.l. The reach is in the shape of a pool, about 8 m wide. The substrate consists mostly of coarse gravel, covered partly by mosses and algae. The surrounding vegetation is composed mainly of heath species and dwarf willow (Fig. 3d).

Station 5 (UTM32N, 6812449 N, 0491405 E) is located at 1301 m a.s.l., 200 m downstream the outlet of the small lake Brurskardtjern. The stream is 3.5 m wide. The bed sediment consists of coarse gravels and boulders covered partly by mosses and algae. The surrounding vegetation is dominated by heath species and dwarf willow (Fig. 3e).

Station 6 (UTM32N, 6813316 N, 492053 E) is situated at 1351 m a.s.l in a small stream above the lake, Brurskardtjern. The stream is about 1.5 m wide and the substrate consists mainly of coarse gravels covered partly by mosses. The vegetation is dominated by heath species (Fig. 3f). After snowmelt this location is mainly groundwater fed (Sand 1997).

Following the vegetation zone definition of Østhagen & Egeli (1978): Station 1 and 2 belongs to the subalpine zone (1090-1200 m a.s.l), and station 3-6 to the low alpine zone (1200-1400 m a.s.l).

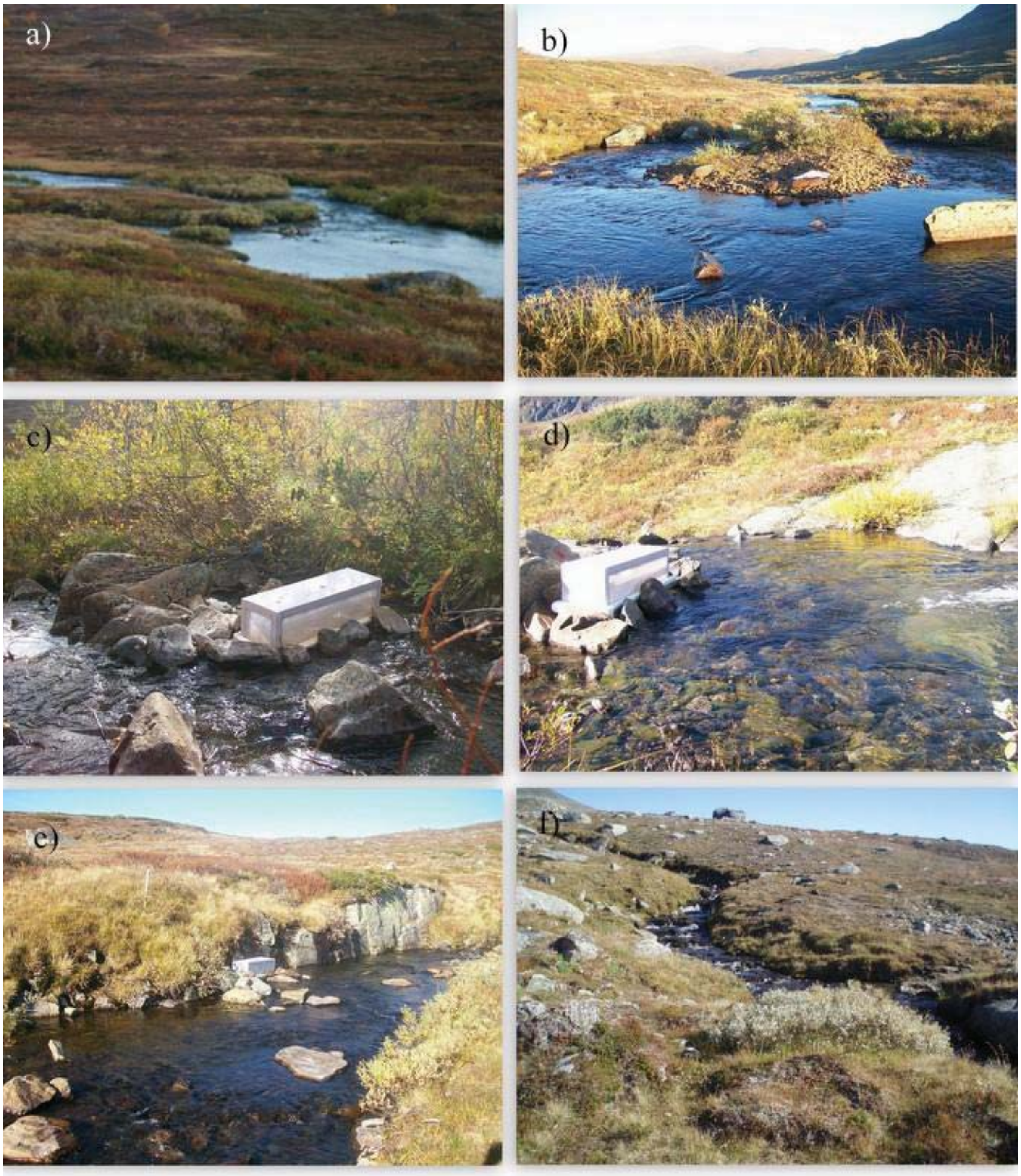

Figure 3. Pictures from study reaches in Øvre Heimdalen: a) station 1, b) station 2, c) station 3, d) station 4, e) station 5, f) station 6 (Photo: Nina K. Stein Helland).

3. Methods

3.1. Sampling and laboratory analysis

The physical protocol from the international co-operative project "Arctic and Alpine Stream Ecosystem Research (AASER)" (Brittain & Milner 2001), has formed the basis for the sampling programme in this thesis, although some adjustments have been made during sampling and laboratory analyzes.

The field surveys were carried out in 2009 during three periods: 24-25 June, 28-29 July and 13-16 September.

Reach description

Each station consisted of 15 meter long reaches, identified and marked with spray paint during first field period. The width of channels was measured and a brief registration of terrestrial vegetation was undertaken.

Temperature

Digital loggers (Minilog 10000), on loan from the Norwegian Water Resources & Energy Directorate (NVE), were used to record temperature at each station during the field season. There is a permanent logger at station 1, which records temperature throughout the year. At stations 2a, 2b, 3 and 4 loggers was placed out on 29.05.09. At station 5 the logger was placed out 24.06.09, and taken up 22.09.09 together with log at station 4, due to ice and snow condition at high altitude. Remaining loggers registered temperature until 6.10.09. Loggers scanned every other hour during the field season.

Invertebrate sampling

Benthic samples were taken by using a kicking technique (Frost et al. 1971). This method is widely used when sampling invertebrates in running water and is considered a semi-quantitative method (Bremnes & Saltveit 2005). The substratum was disturbed by kicking for a 30 seconds period while a standard pond-net (30 x 30 cm opening and a mesh size of 250 microns) was placed downstream. The pond net was then inverted into a sampling tray and content placed in plastic bags and preserved in 70 % ethanol. Three kick samples were taken at each station, three times during the survey, altogether 54 samples. When returning to the laboratory, invertebrates from the orders Plecoptera, Ephemeroptera and Trichoptera were picked from the kick samples under a dissecting microscope. The organisms were then sorted and identified, to species where possible. The species was also sorted according to their feeding habits, in five functional feeding groups: shredders, collectors, scrapers (grazers), piercers and predators. The following taxonomic handbooks were used:

Plecoptera: (Lillehammer 1988), (Brittain & Saltveit 1996).

Ephemeroptera: (Elliott et al. 1988; Engblom 1996).

Trichoptera: (Wallace et al. 1990), (Edington & Hildrew 1995), (Solem & Gullefors 1996).

Chlorophyll *a* estimation

To assess the biomass of epilithic algae, three stones were randomly collected at every station during each field period. Approximately 3 cm x 3 cm from the upper surface on each stone, was scraped with a toothbrush. The scrapings were then washed with water into a Millipore filter funnel with 4.7 cm GF/C filter paper, with an attached hand-hold pump (Brittain et al. 2001). The filter papers were folded into larger filter papers and stored in sample bottles. Samples were stored in a freezer on return to the laboratory at UMB.

In the laboratory, chlorophyll *a* was extracted by the following procedure: Filter papers and 1.5 ml 90 % acetone were put in eppendorf-tubes and processed in a tissue grinder (*Reutsch NM301)* for three minutes at 25 $^{1}/s$. After grinding, samples were flushed into screw-cap centrifuge tube with additional 3.5 ml acetone and extracted for a period of two hours in a refrigerator at 4°C. The samples were then centrifuged (*Centrifuge type: Universal 16, Hettich*) for two minutes at 4000 rpm.

The samples were analyzed using a spectrophotometer (APHA 1995). Result after the spectrophotometric procedure showed a lot of "disturbance" in the samples. Due to this problem, the optical density values were corrected to avoid overestimated amounts of Chlorophyll *a*, using following equations (Solhaug, K.A. pers.med):

a) OD664-0.36(OD600-OD700)-OD700

b) OD647-0.53(OD600-OD700)-OD700

c) OD630-0.70(OD600-OD700)-OD700

Calculation of Chlorophyll *a* concentration was performed by inserting the corrected optical densities in following equation (APHA 1995):

$$C_a = 11.85(OD664) – 1.54(OD647) – 0.08(OD630).$$

After determining the concentration of pigment in the extract, the amount of pigment per unit volume was calculated as follows (APHA 1995):

$$\text{Chlorophyll } a\text{, mg/m}^3 = \frac{C_a * \text{extract volume, L}}{\text{Volume of sample, m}^3}$$

Estimation of particulate organic matter (POM)

Sequential loss of ignition (LOI) is a common used method to estimate the organic content of sediments (Dean 1974; Heiri et al. 2001). In this thesis the content from the kick samples, after removing the invertebrates and visible autochthonous material (mosses), was used to determine the percentage amount of organic matter at different sampling sites and time of the year.

The contents of each kick sample were dried at 60°C for one hour and cooled down to room temperature. Each sample was then weighed and provided the basis for further loss weight calculations (Dean 1974). In the next step samples were ashed in a muffle furnace at 550°C for four hours and placed in a desiccator to cool down to room temperature. Heiri et al., 2001 suggested that four hours is a reasonable exposure time at 550°C. The loss of ignition was then calculated. Thereafter the organic content in the kick sample was estimated in grams for each sample. For large samples and to take account of differences in sample sizes, ca. 0.5 grams from each sample were weighed out, before being placed in the muffle furnace. This was decided after testing with whole samples proved to be unsatisfactory, indicating that samples of the same weight gave more consistent results.

Substratum size

Substratum size was determined at each station by visual assessment, described as percentages of following categories: boulders (>20 cm), coarse gravels (5-20 cm), fine gravels (0.2-5 cm) and inorganic sand (0.01-0.2 cm) (Brittain et al. 2001).

Grain size distribution

The Wolman pebble count was used to characterize the channel bed sediment in the survey reaches (Wolman 1954). Sampling was carried out by randomly picking 100 stones from the streambed and measuring the B-axis length with a ruler. The B-axis length is the intermediate length of a stone. This was performed once at each station.

Micro-scale stability

Depth and flow velocity were recorded at the sites of every kick sample. Flow velocity was measured twice with a current meter, in the centre of each sampling area.

Pfankuch index

The stream bottom component of the Pfankuch index of stream stability (Pfankuch 1975) was used to describe the stability of the stream bottom in the six survey reaches. Five variables were visually recorded at each site during the first field period in June. The variables included in the index are rock angularity, bed-surface brightness, particle packing, per cent stable materials, scouring and aquatic vegetation. Each variable is given a score and summed to provide an overall index of channel stability. In the Pfankuch index, high scores represent unstable channels and low scores represent stable channels.

Discharge

The salt dilution method was used to measure discharge during the field survey periods. This is a traditional method for measurement of water discharge in turbulent streams, where salt is injected suddenly into the stream and the dilution is measured by means of electrical conductivity (Hongve 1987). Dry fine-grained salt (NaCl) in volume ranging from 100 to 400 grams was dropped into the stream at a site with turbulent flow. At a distance downstream from the injection of the salt, changes in dilution over time were measured with a conductivity meter. Registration started when the salt was dropped and registered at 10 seconds intervals until dilution level returned to the original conductivity. Conductivity of dissolved NaCl varies with temperature (Hongve 1985), so water temperature was also measured at each site.

Calculation of discharge was made using the equation (Hongve 1985):

$$q = \frac{P*10^{6}*0{,}214}{k_{T}*\int_{0}^{t} \Delta \text{ kond } .dt} \quad \text{L/s}$$

3.2. Statistical analysis

In this thesis, species composition was analysed with the two ordination techniques Detrended Correspondence Analysis (DCA) and Canonical correspondence analysis (CCA), using the ordination analysis program CANOCO version 4.5 (Ter Braak & Smilauer 2002). Ordination is the collective term for multivariate techniques that arrange sites along axes on the basis of data on species composition. Ordination methods have been used by ecologist since the early 1950s (Leps & Smilauer 2003). The aim of ordination is to arrange points such that points that are close together correspond to sites that are similar in species composition, and points that are far apart correspond to sites that are dissimilar in species composition (Ter Braak 1995).

Detrended Correspondence Analysis (DCA) is an indirect (unconstrained) ordination method, which provides a basic overview of the compositional gradients in the data (Leps & Smilauer 2003). The DCA results are displayed in an ordination diagram with sites and species represented by circles and triangles, respectively. DCA was used to illustrate gradients of species composition change in relation to altitude and time of year. The data was analysed as species presence/absence in the six different reaches on three different sampling dates.

Canonical Correspondence Analysis (CCA) is a direct (constrained) ordination method. The aim of constrained ordination is to find the variability in the species composition that can be expected by the measured environmental variables (Leps & Smilauer 2003). The result of CCA is displayed in an ordination diagram with sites and species represented by points, and environmental variables represented by arrows. The species and site points jointly represent the dominant patterns in community composition insofar as these can be explained by the environmental variables (Ter Braak 1986). The data was analysed as species presence/absence in the six different reaches on three different sampling dates, and related to ten measured environmental variables. For the environmental variables that were recorded more than once each sampling period, an average value was calculated for the ordination analyse.

Simple linear regression is used to explore the relation between two variables (Løvås 2004); in this thesis used to explore the relationship between number of species and altitude using the statistical program Minitab 15. A significance value $\alpha < 0.05$ was used.

4. Results

4.1. Invertebrate fauna

The total number of identified species collected during sampling was 31. The Trichoptera were represented by 7 species, Ephemeroptera by 8 species and Plecoptera by 16 species (Tab 1). In addition to the identified species, some specimens belonging to the genera *Bäetis, Leuctra, Isoperla* and *Limnephilus* were not identified to species. These were not included in the ordination analyses.

The highest densities were recorded in the outlet of Øvre Heimdalsvatn (station 1), largely due to high numbers of the trichopteran filter feeder, *Polycentopus flavomaculatus*. The second highest densities were recorded at station 5, below the small lake Brurskardtjern, where Baetidae stood for almost 80 % of the recorded density. The lowest densities were found at station 4 (Tab. 1).

The most abundant species was *Bäetis rhodani*, recorded in high numbers at all stations. The ephemeropteran species *Ephemerella aroni* and *Siphlonurus lacustris* were recorded only by one specimen each, as was the plecopteran species *Capnia bifrons* (Tab. 1).

The highest numbers of species were found in the inlet of Øvre Heimdalsvatn (station 2) and the lowest number in the inlet stream of Brurskardtjern (station 6), situated at the highest altitude in the survey (Tab. 1).

Table 1. Number of Trichoptera, Ephemeroptera and Plecoptera individuals recorded at stations 1-6 in Øvre Heimdalen.

Location	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
Trichoptera						
Philopotamus montanus (Donovan, 1813)		7	8			
Plectronemia conspersa (Curtis, 1834)		4	20	41	38	
Polycentopus flavomaculatus (Pictet, 1834)	589					
Rhyacophila nubila (Zetterstedt, 1840)	10	10	10	24	21	
Apatania sp.		10	1			62
Hydroptila sp.	21				4	
Oxyethira sp.	158			1		
Limnephilus spp.	7	1	1		2	35
Ephemeroptera						
Acentrella lapponicus (Bengtsson, 1912)		69	8	1		
Ameletus inopinatus Eaton, 1887		10	3	27	7	
Bäetis fuscatus (Linnaeus, 1761)	41	1		2		
Bäetis rhodani (Pictet, 1843-45)	76	175	184	60	194	229
Bäetis subalpinus Bengtsson, 1917		6	5	8	4	
Ephemerella aroni (Eaton, 1908)		1				
Leptophlebia marginata (Linnaeus, 1767)	15					
Siphlonurus lacustris Eaton, 1870	1					
Bäetis spp.	198	109	159	58	455	63
Plecoptera						
Amphinemura standfussi (Ris, 1902)	1	21	27	25	1	3
Amphinemura sullicollis (Stephens, 1836)	15				14	
Brachyptera risi (Morton, 1896)		41	4			2
Capnia bifrons (Newman, 1839)					1	
Diura nanseni (Kempny, 1900)		5	18	32	22	
Isoperla obscura (Zetterstedt, 1840)	1				1	4
Isoperla grammatica (Poda, 1761)	21					
Leuctra digitata Kempny, 1899		33	6	17		
Leuctra fusca (Linné, 1758)	15	1				
Leuctra hippopus Kempny, 1899	17	3	1	20	32	
Leuctra nigra (Olivier, 1811)		7	1	6		
Nemoura cinerea (Retzius, 1783)	2	11	16		6	137
Nemoura avicularis Morton, 1894		1	2			
Nemurella pictetii Klapálek, 1900						11
Protonemura meyeri (Pictet, 1841)		15	10	4	8	
Taeniopteryx nebulosa (Linné, 1758)	24					
Isoperla spp.		1		1		
Leuctra spp.	1	49	9	20	13	4
Total number of specimens	1213	591	493	347	823	550
Number of Trichoptera species	4	4	4	3	3	1
Number of Ephemeroptera species	4	6	4	5	3	1
Number of Plecoptera species	8	11	9	6	8	5
Total number of species	16	21	17	14	14	7

Station 1

At station 1, in the outlet of the lake Øvre Heimdalsvatn, 16 species were recorded. Four Trichoptera species were collected: *Polycentropus flavomaculatus, Rhyacophila nubila, Hydroptila* sp. and *Oxyethira* sp. *P. flavomaculatus* that dominated the fauna with 589 individuals, was recorded only at this site. *Oxyethira* sp. was also numerous with 158 individuals (Tab. 1).

Four ephemeropteran species: Bäetis *fuscatus, Bäetis rhodani, Leptophlebia marginata* and *Siphlonurus lacustris* were collected at this site. *L. marginata and S .lacustris* were found only at this site, *S. lacustris* was represented by only one specimen (Tab. 1).

Eight species of Plecoptera were recorded (Tab. 1): *Amphinemura standfussi, A. sullicollis, Isoperla obscura, I. grammatica, Leuctra fusca, L. hippopus, Nemoura cinerea* and *Taeniopteryx nebulosa. I. grammatica* and *T. nebulosa* were only recorded at this site. Only one specimen of *A. standfussi* and *I. obscura* was recorded, while two specimens of *N. cinerea* were recorded.

Station 2

Twenty-one species, the highest number in the survey, were found in the inlet of the lake Øvre Heimdalsvatn (Tab. 1). The Trichoptera were represented by the four species: *Philopotamus montanus, Plectronemia conspersa, Apatania sp.* and *Rhyacophila nubila.*

Six ephemeropteran species were recorded, of which *Bäetis rhodani* and *Acentrella lapponicus* dominated. *Ameletus inopinatus, Bäetis fuscatus, B. subalpinus* and *Ephemerella aroni* were present in low numbers.

Eleven plecopteran species were collected. Species from the genus *Leuctra* dominated amongst the Plecoptera, together *with Brachyptera risi, Amphinemura standfussi* and *Protonemura meyeri*. *Diura nanseni, Nemoura cinerea* and *N. avicularis* were only recorded in low numbers.

Station 3

At station 3, situated in the mountain birch forest, a total of 17 species were recorded (Tab. 1). The Trichoptera were represented by *Philopotamus montanus, Plectronemia conspersa, Rhyacophila nubila* and a single specimen of *Apatania* sp.

Bäetis rhodani dominated among the Ephemeroptera. *Acentrella lapponicus, Ameletus inopinatus* and *Bäetis subalpinus* were recorded in low numbers.

Nine plecopteran species were recorded at this site. The dominating species were *Amphinemura standfussi, Diura nanseni, Nemoura cinerea* and *Protonemura meyeri*. *Brachyptera risi, Leuctra digitata, L. hippopus, L. nigra and Nemoura avicularis* were also present.

Station 4

At station 4, situated just above the timberline, 14 species were recorded (Tab. 1). Three trichopteran species were recorded: 41 specimens of *Plectronemia conspersa* and 24 specimens of *Rhyacophila nubila*. *Apatania* sp. was recorded by only a single specimen.

Five ephemeropteran species were recorded: *Ameletus inopinatus* and *Bäetis rhodani* were the dominating species, together with a few individuals from the species *Bäetis fuscatus, B. subalpinus* and *A. lapponicus.*

The six Plecoptera species recorded at this site were *Amphinemura standfussi, Diura nanseni, Leuctra digitata, L. hippopus, L. nigra* and *Protonemura meyeri.*

Station 5

A total number of 14 species were recorded at station 5 (Tab. 1). Three trichopteran species were recorded. *Plectronemia conspersa* and *Rhyacophila nubila* represented respectively by 38 and 21 individuals. Four individuals of *Hydroptila* sp. were recorded.

The Ephemeroptera were dominated by *Bäetis rhodani*; a few representatives from the two species *B. subalpinus* and *Ameletus inopinatus* were also present.

Eight plecopteran species were recorded. *Amphinemura sullicollis, Diura nanseni* and *Leuctra hippopus* clearly dominated the Plecoptera fauna. *Nemoura cinerea* were represented by six specimens and *A. standfussi, Capnia bifrons* and *Isoperla obscura* by a single specimen each.

Station 6

At the highest situated station in the survey, in the inlet stream to the lake Brurskardtjern, only 7 species were recorded (Tab 1.). *Apatania* sp. was the only trichopteran specie recorded. In addition 35 specimens in the genus *Limnephilus* were collected, but not identified to species.

Bäetis rhodani were recorded in high numbers and was the only ephemeropteran recorded at this site. Five plecopteran species were recorded. There were high numbers of *Nemoura cinerea* at this station. Other Plecoptera present were: *Amphinemura standfussi, Brachyptera risi, Isoperla obscura* and *Nemurella pictetii*. The latter species was only found at this site.

4.2. Functional feeding groups

The percentage composition of species according to their feeding habit is displayed in figure 4. At station 1, shredders are the largest group, followed by scrapers (grazers) and predators. The largest group of piercers were found at this station (12.5 %). Station 2 and 3 showed similar composition, shredders being the dominant group in both cases. Scrapers (grazers) were the dominant feeding group at station 4. At station 5, shredders, scrapers (grazers), and predators, respectively, dominated the fauna. At station 6, shredders clearly dominated the fauna, while collectors and piercers were lacking.

When looking at percentage composition of specimens after their feeding habit (Fig. 5), rather than species composition, the picture is quite different. Collectors dominated at station 1, while scrapers (grazers) clearly dominated the other stations.

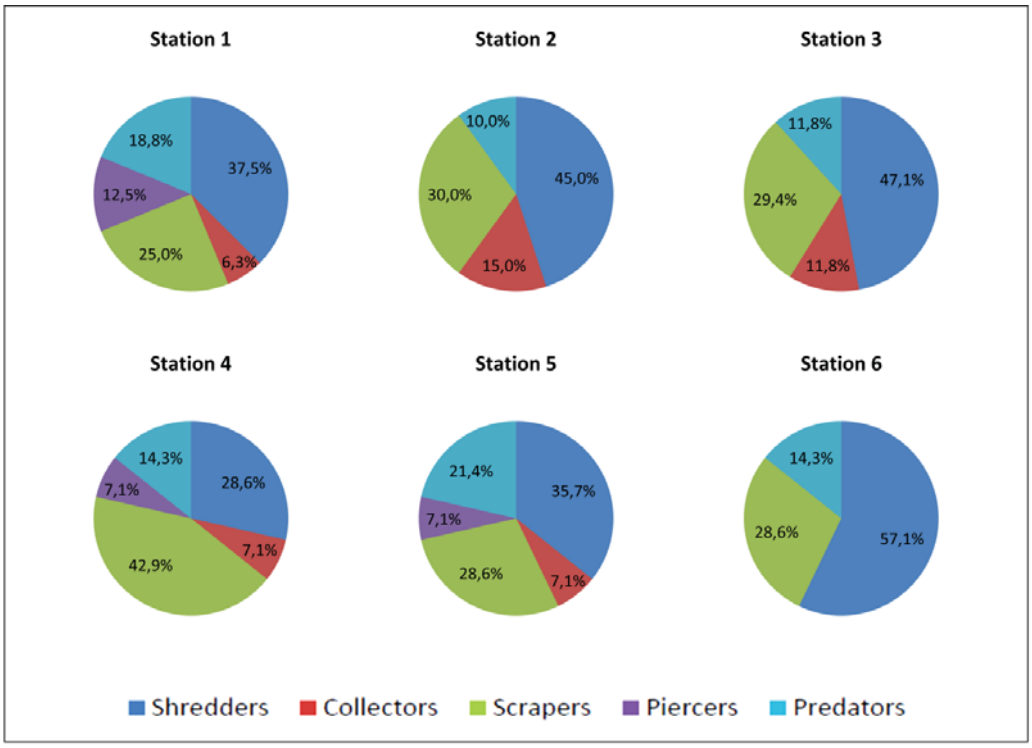

Figure 4. Percentage composition of species according to their feeding habits (functional feeding group) at stations 1 to 6 in Øvre Heimdalen

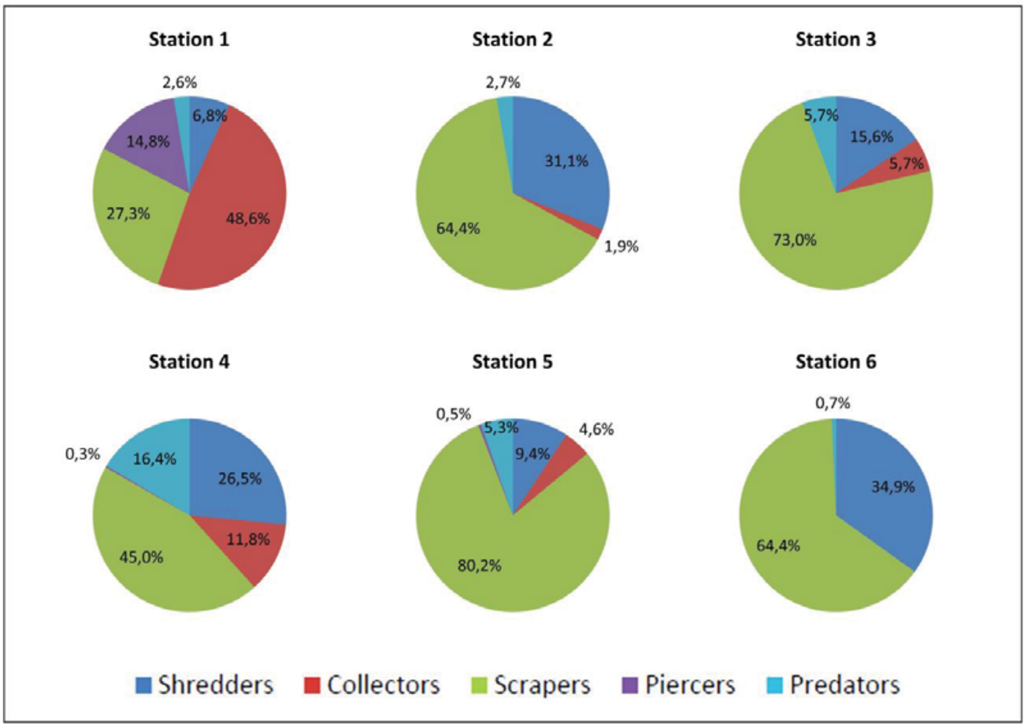

Figure 5. Percentage composition of specimens according to their feeding habits (functional feeding group) at stations 1 to 6 in Øvre Heimdalen.

4.3. Environmental variables

There was a significant decrease in number of Ephemeroptera, Plecoptera and Trichoptera (EPT) species with increasing altitude ($r^2 = 0.73$, $p = 0.029$) (Fig. 6).

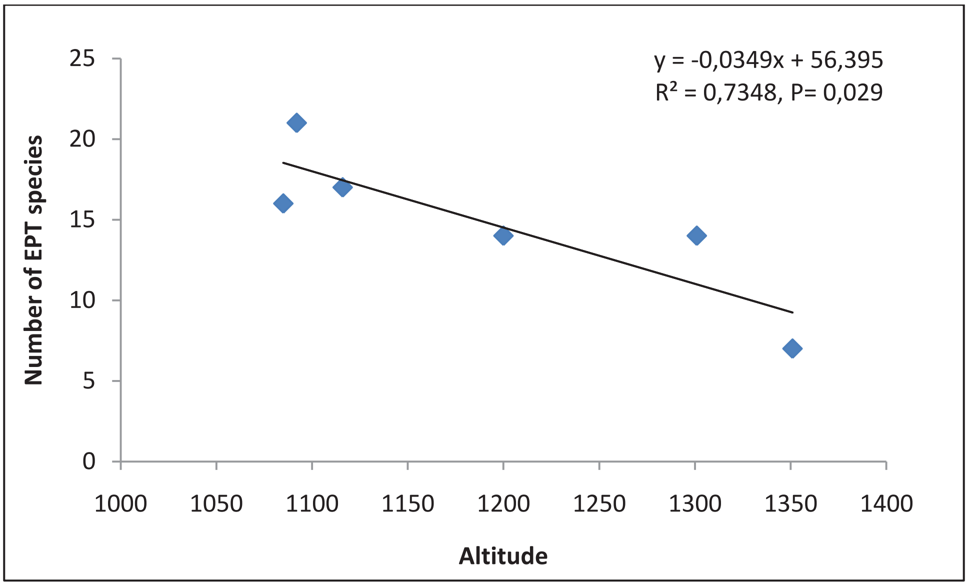

Figure 6. Number of Trichoptera, Ephemeroptera and Plecoptera species at different altitudes in Øvre Heimdalen valley.

Temperature regimes differed between stations during the field period. Station 1 had the highest recorded temperatures during the summer of 2009. Maximum temperature recorded was 18.7 °C, minimum temperature was 7.6 °C and the mean temperature was 12.0 °C. The total number of day-degrees during the field season was 1094. Station 2 had second lowest temperatures, with 807 day-degrees during the field season. Station 3 and 4 had similar temperatures recorded, 904 and 907 day-degrees, respectively, during the field season. Station 5 had the second highest recorded temperature and 939 day-degrees. The lowest temperatures were recorded at station 6, with minimum temperature 3.5 °C, maximum temperature 12.65 °C and 7.1 °C as mean temperature. The day-degrees during the field season were 650 (Tab. 2).

Table 2. Mean temperature, maximum temperature, minimum temperature and day-degrees in study reaches from 24.06. to 22.09.2009

Reach	Mean (°C)	Min. (°C)	Max. (°C)	Day-degrees (D°)
1	12,0	7,6	18,7	1094
2	8,9	4,8	12,7	807
3	9,9	5,3	16,7	904
4	9,9	5,3	16,9	907
5	10,3	6,0	17,5	939
6	7,1	3,5	12,7	650

The percentage amount of particulate organic matter (POM) varied between stations, kick-samples and sampling dates. Station 1 and station 6 had in sum the largest recorded percentages of POM in kick samples (Fig. 7).

The Chlorophyll *a* estimation showed for the most part small amounts of ephilithic algae in the study reaches, although some higher levels were recorded at station 1, 4, 5 and 6. The highest level of Chlorophyll *a* was recorded at station 4 (Fig. 7).

Depth measured at the same positions as the kick samples, showed little variance between the stations (fig 4). Current velocity showed fastest levels at station 2 and 3, while station 4 had the slowest current velocity (Fig. 7).

Discharge levels clearly separated station 1 from the other survey reaches, reaching over 600 l/s in September. Second highest discharge level recorded at station 2, while the other stations had low discharge levels, not exceeding 17 l/s, during the field season (Fig. 7).

Index scores in the stream bottom component of the Pfankuch index of stream stability ranged from 19 to 37, all indicating fairly stable conditions. Station 1 and 2 scored, respectively, 32 and 37. Station 3 and 6 scored both 26, station 4 scored 24 and station 5 had index score 19, the lowest score recorded, indicating high stability (Fig. 7).

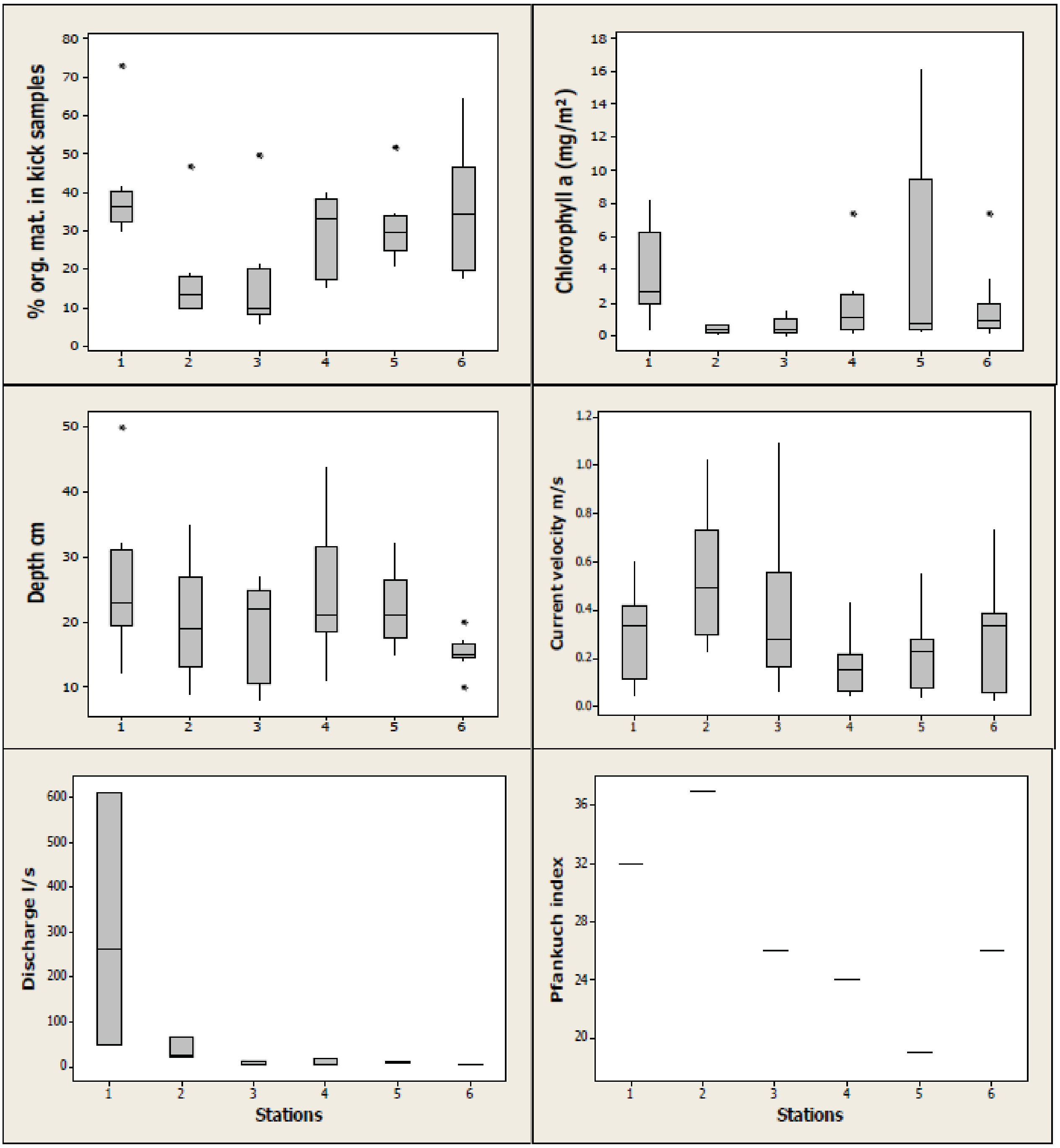

Figure 7. Box-plots for six environmental variables in total of six stations in Øvre Heimdalen. The vertical boxes depict the interquartile range (Q25-Q75) around the median (horizontal thick line). Outliners, falling outside the interval, are represented by asterisk (*). Only single values are plotted for Pfankuch index because its value was constant during the survey.

The recorded bed-sediment showed that coarse gravels were the dominant substrate in all reaches, except station 2, where fine gravels stood for 50 % of the substrate. Inorganic sand was only recorded at this station. Percentage of boulders ranged from 5 to 30. Station 1 had the longest average B-axis length of stones recorded with 6.24 cm, while station 2 had the shortest average B-axis length with 4.69 cm.

4.4. Detrended Correspondence Analysis (DCA)

The results of the DCA analysis (absence/presence) are summarised in Table 3. The first and second ordination axes explained 42.8 % and 34 %, respectively, of the total variability.

Table 3. Summary of the DCA analyse. Eigenvalue, length of gradient, cumulative percentage variance of species data are listed.

Axes	1	2	3	4
Eigenvalue	0.428	0.340	0.100	0.048
Length of gradient	2.976	2.890	1.928	1.266
Cumulative % variance of species data	20.1	36.1	40.9	43.1

The DCA ordination diagram is displayed in figure 8. Species *like Siphlonurus lacustris, Polycentropus flavomaculatus, Leptophlebia marginata, Taeniopteryx nebulosa* and *Isoperla grammatica* found only at station 1 showed low coordinate scores, both on first and second axis. In contrast, *Nemurella pictetii* found only at station 6, showed high coordinates on both first and second axis. Species like *Bäetis rhodani* and *Amphinemura standfussi,* found at all stations showed medium scores on both axis. The station points did not show a clear pattern of increasing altitude along the first axis; station 2-6 showing approximately the same coordination scores. There is no obvious difference in distribution between the orders Trichoptera, Ephemeroptera and Plecoptera. There was little variation amongst sampling dates and the majority of the variation appeared between stations. Station 1 and station 6 tended to form two separate groups, while station 2, 3, 4 and 5 tended to form a single group together. This indicates change in species composition from the inlet of Brurskardtjern to Brurskardbekken and further a change in species composition from Brurskardbekken and to the outlet of Øvre Heimdalsvatn.

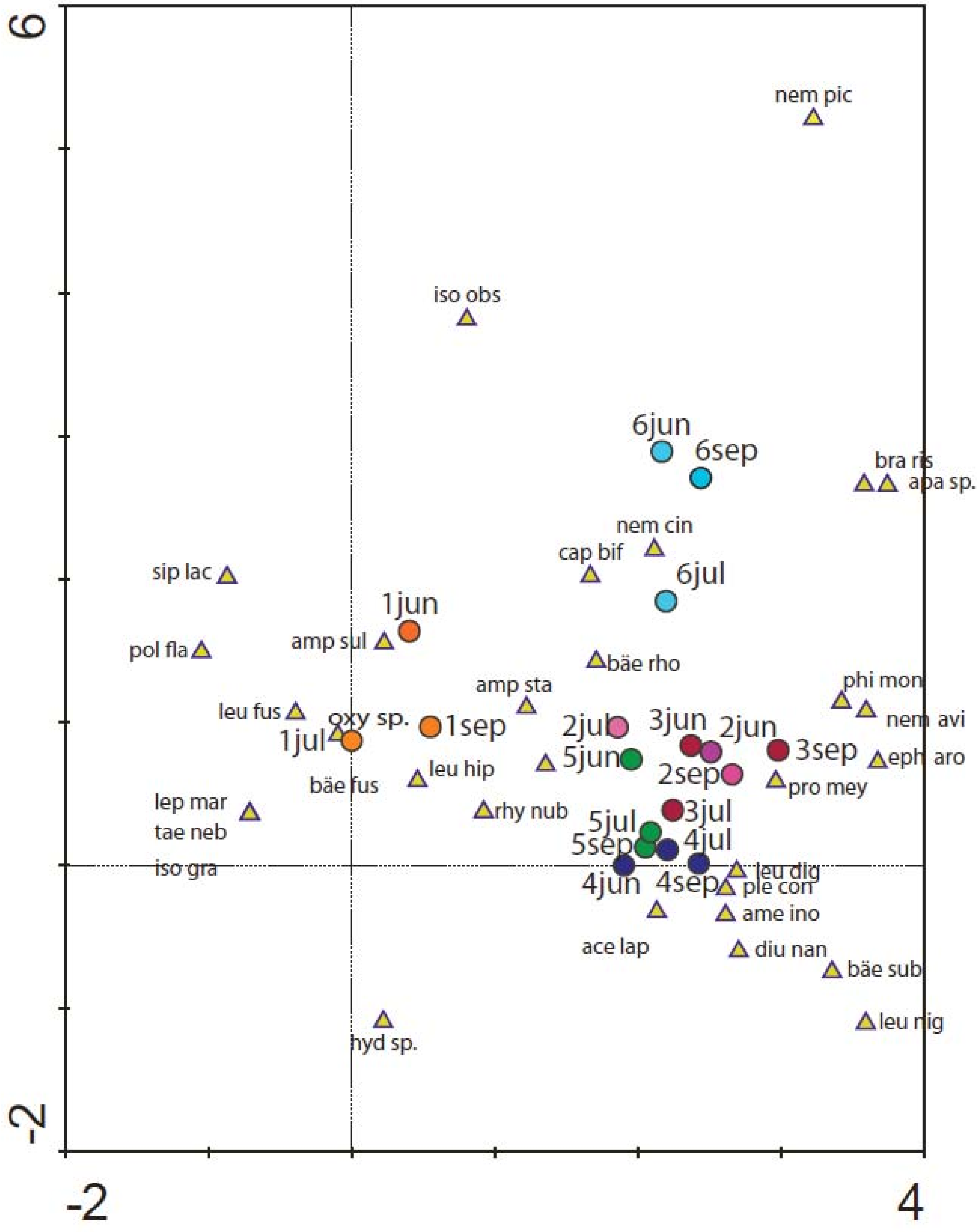

Figure 8. Detrended Correspondence Analysis (DCA) ordination diagram of species (Δ) found at the six stations (○) in June, July and September sampling. First axis is horizontal, second axis vertical. Descriptions of the site and species abbreviations see Appendix 1.

4.5. Canonical Correspondence Analysis (CCA)

Results from the Canonical correspondence analysis (CCA) are summarized in table 4. The first and second ordination axes explained 42 % and 25.8 %, respectively, of the total variability.

Table 4. Summary of the CCA analyse. Eigenvalue, species-environmental correlations, cumulative percentage variance of species data and cumulative percentage variance of species-environmental relation are listed.

Axes	1	2	3	4
Eigenvalue	0.420	0.258	0.213	0.177
Species-environmental correlations	0.994	0.918	0.953	0.921
Cumulative % variance of species data	19.8	31.9	41.9	50.2
Cumulative % variance of species-environmental relation	29.2	47.2	62.0	74.3

CCA results are displayed in figure 9 and 10. Station 2-6 shows low coordinates on axis 1, while station 1 separates from the other station, showing high coordinates on axis 1. On axis 2 station 6 shows high coordinates on axis 2 and July samples from station 2,3,4, and 5 show low coordinates on axis 2 (Fig. 9).

In figure 9 the species *Siphlonurus lacustris, Polycentropus flavomaculatus, Leptophlebia marginata, Taeniopteryx nebulosa* and *Isoperla grammatica* found only on station 1 show high coordinates on axis 1. *Nemurella pictetii* found only on station 6 show low coordinates on axis 1 and high coordinates on axis 2. This corresponds with the coordinates of station 1 and 6 in figure 9. *Bäetis rhodani*, the most abundant species is placed where axis 1 and axis 2 cross. The other species distribute scattered along axis 1 and 2, this is more difficult to interpret.

As displayed by length of arrows discharge, organic material, B-axis, and temperature are the main explanatory variables in this data ordination (Fig. 9 and 10). Discharge, organic material, B-axis length and percentage of boulders are the most important contributors to axis 1 and minimum and mean temperature the most important contributors to axis 2. Depth at time of survey, chlorophyll *a*, current velocity and Pfankuch index played a less important role in this data ordination.

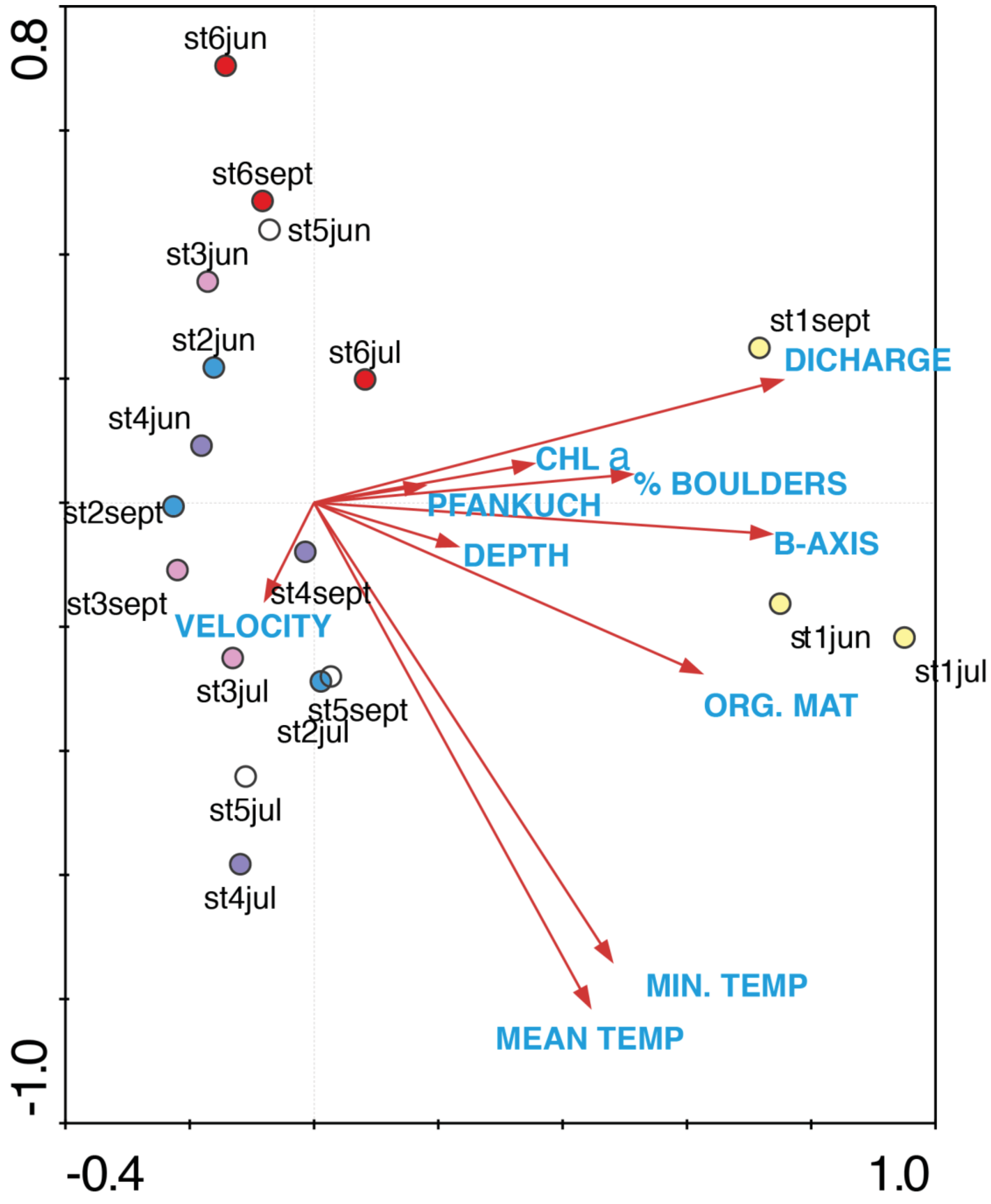

Figure 9. Canonical correspondence analysis (CCA) based on the invertebrate fauna at the six stations on June, July and September samplings by 10 environmental variables. First axis is horizontal, second axis vertical. Distribution of the six stations on the three sampling months (○) is displayed. The environmental variables are shown as arrows. Descriptions of the site and species abbreviations see Appendix 1. For descriptions of environmental abbreviations and plotted environmental values see Appendix 2.

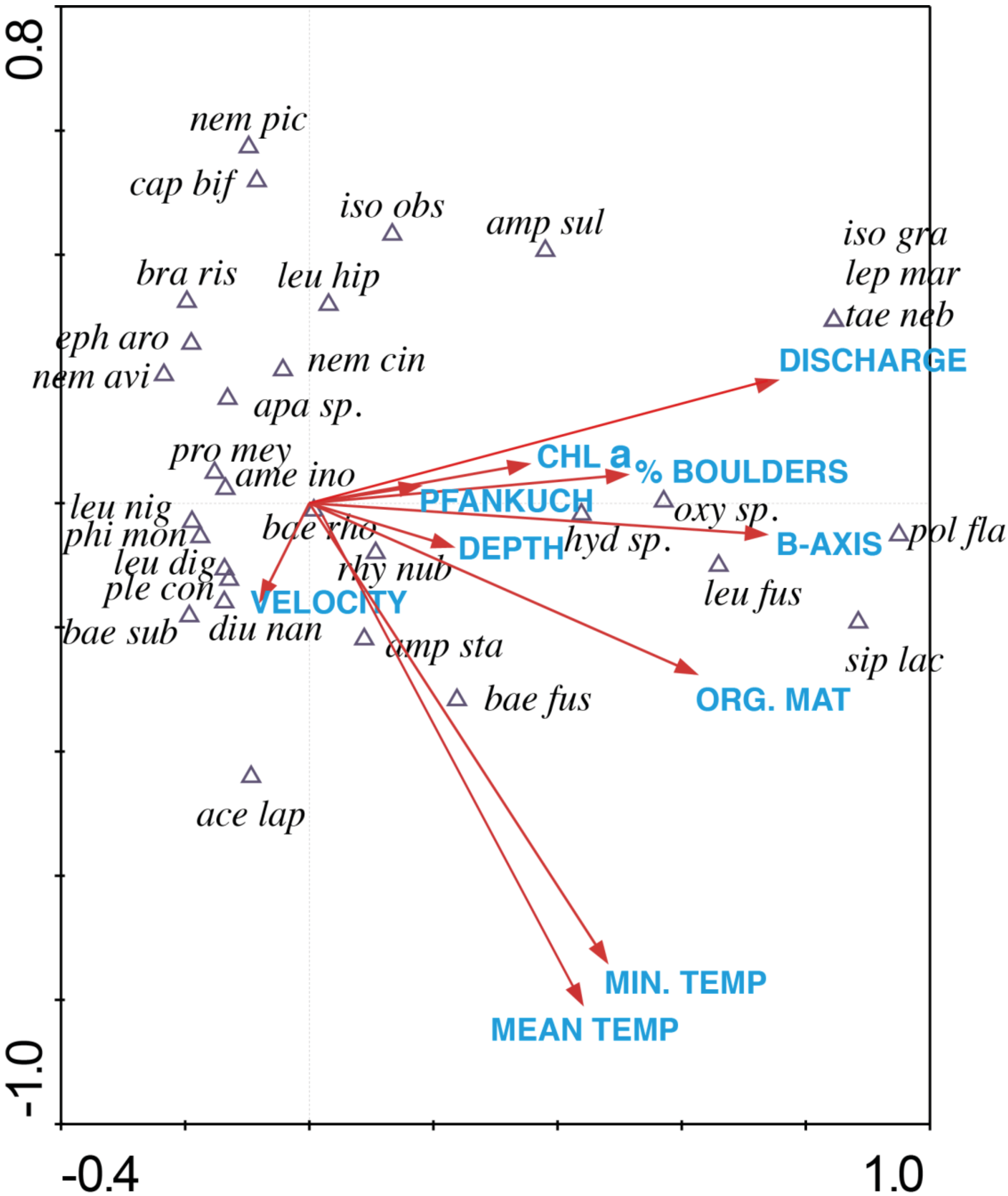

Figure 10: Canonical correspondence analysis (CCA) based on the invertebrate fauna at the six stations on June, July and September samplings by 10 environmental variables.. Distribution of species (Δ) is displayed. The environmental variables are shown as arrows. First axis is horizontal, second axis vertical Descriptions of the site and species abbreviations see Appendix 1. For descriptions of environmental abbreviations and plotted environmental values see Appendix 2.

When looking at the CCA summary (Tab. 4), the percentage variance of species data, explained by the first axis is very close to that explained by the first axis in the unconstrained DCA (20.1 in comparison with 19.8) (Tab. 3). The first eigenvalue of CCA is only slighter higher than the first eigenvalue of DCA (0.428 in comparison with 0.420). In the CCA, the species-environment correlations of the four first axes are all high. This suggests that the measured environmental variables are sufficient to explain the major variation among the invertebrate samples.

5. Discussion

5.1. Invertebrate fauna

A total of 31 species were identified from the Øvre Heimdalen stream system. The Trichoptera were represented by 7 species, Ephemeroptera by 8 species and Plecoptera by 16 species. All species recorded in this study, except the trichopteran species *Hydroptila* sp., were also recorded in Øvre Heimdalen by Lillehammer & Brittain (1978). This study did not record all species expected to be present. For example, the plecopteran species *Capnia atra* was not recorded, although it have been found to be common in the inlets streams of Øvre Heimdalsvatn (Lillehammer & Brittain 1978). One likely reason for this is that only one stream was sampled in this study. Missing species could also be rare and difficult to detect without very high sampling effort (Aagaard et al. 2004). Also species like *C. atra* emerge very early (Lillehammer & Brittain 1978) and are only present as nymphs from late autumn onwards (Brittain pers.comm.).

The highest number of species was recorded in the inlet of the lake Øvre Heimdalsvatn, while the highest densities were in the outlet of the lake, corresponding to the findings of Lillehammer & Brittain (1978). At station 5 at 1301 m a.s.l. 14 species were recorded, while only 7 species were recorded at station 6, located at 1350 m a.s.l. in the inlet stream of Brurskardtjern. The explanation for the reduction of species, are probably that station 6 is situated in the transition zone between the low-alpine and the mid-alpine zones, where there is reduction in riparian vegetation and lower temperatures (Reiso & Brittain 2000 b).

Hydroptila sp. has not been recorded in Øvre Heimdalen earlier (Lillehammer & Brittain 1978; Reiso & Brittain 2000 b). 21 specimens were recorded in the outlet of Øvre Heimdalsvatn. In the Dovrefjell Mountains, Solem (1985) recorded *Hydroptila tineoides* and *Hydroptila forciptata* in the subalpine zone, ranging from 870-1080 m a.s.l. and *H. tineoides* was recorded in the outlet of the lake Gåvålivatn situated in the subalpine zone. Aagaard et al. (2004) recorded *Hydroptila simulans, H. tineoides,* and *H. forciptata* in the river Atna at 380 m a.s.l. Four specimens of *Hydroptila* sp. were also recorded 200 m downstream of the lake Brurskardtjern, situated 1301 m a.s.l. in the low alpine zone. This may be the highest altitude in Norway that *Hydroptila* sp. has been recorded. *Oxyethira* sp., also belonging to the Hydroptilidae, was recorded in relatively high numbers in the outlet of Øvre Heimdalen. This species were recorded in Øvre Heimdalen by Lillehammer & Brittain (1978), but not recorded in the outlet of Øvre Heimdalsvatn.

The larvae of family Hydroptilidae, are very small, only 2.5-7.5 mm in length when fully grown, and the larvae grow rapidly (Wallace et al. 1990). *Hydroptila forciptata* had only two weeks of flight period in Dovrefjell Mountains (Solem 1985). The small body size and the short life history can be an explanation why *Hydroptila* sp. and *Oxyethira* sp. had few former records from Øvre Heimdalen.

The trichopteran fauna in the outlet of Øvre Heimdalsvatn was dominated by the filter-feeder *Polycentropus flavomaculatus*, while the filter-feeder *Plectronemia conspersa* dominated the upper reaches of Brurskardbekken. The predator *Rhyacophila nubila* was recorded at all stations, except station 6. This correspond with the findings of Reiso & Brittain (2000a), showing that these species occupies a wide range of different habitats in Øvre Heimdalen.

Apatania sp. was recorded in high numbers at station 6, situated at the highest altitude in the survey. *Apatania* species are well adapted to short summers and low temperatures, having a semivoltine life cycle strategy at high altitudes (Solem 1985b). *Apatania zonella* is also a truly Arctic species and is the only Trichoptera recorded from Svalbard (Solem et al. 1977).

Bäetis rhodani was recorded in high numbers at all stations and was the most abundant species in this study. *B. rhodani* is also Norway`s most common Ephemeroptera species in running water (Aagaard et al. 2004). Due to difficulties in identifying first instars nymphs of *Bäetis* correctly, relative high numbers of *Bäetis* specimens was not identified to species. It is expected that most of these belong to the species *B. rhodani* (Brittain pers.comm.). Sand (1997) found that *B. rhodani* had highest densities in lower reaches of Brurskardbekken, while this study had highest densities in the upper reach, situated just downstream of the lake Brurskardtjern. *Bäetis fuscatus* recorded in the outlet of Øvre Heimdalsvatn may have been the species *Bäetis scambus*, recorded in high numbers in the outlet by Lillehammer & Brittain (1978). Nymphs of *B. fuscatus* and *B. scambus* are not easily separated (Elliott et al. 1988).

Plecoptera were widely distributed in the reaches studied, with a total of 16 identified species. *Nemoura cinerea* was the most abundant species at station 6, but had few records at the other stations. *N. cinerea* has a two-year cycle under unfavorable conditions (Brittain 1974) and can be common when few other species are present (Lillehammer 1974), explaining its dominance at station 6, situated at 1350 m a.s.l. *Nemurella pictetii* was only recorded at station 6, but has been recorded in the subalpine zone in previous studies (Lillehammer & Brittain 1978).

5.2. Functional feeding groups

Aagaard (2004) concluded that grazers dominated in the zoobenthos in streams in the treeless alpine region. The reason is most probably that the supply of dead organic material from the riparian vegetation is restricted, while the light conditions provide a good environment for periphyton production. In this study, looking at number of specimens rather than species richness, these conclusions are also true, and scrapers (grazers) were also the dominating functional feeding group in the birch forest. The dominance of *Bäetis* species is also an explanation for this. Other studies have investigated the number of species rather than specimens (Reiso 1999; Reiso & Brittain 2000 b); shredders then became the dominant feeding group in subalpine and low alpine areas in Øvre Heimdalen, as shown in this study.

5.3. Detrended Correspondence Analysis (DCA)

There was not clear altitudinal gradient of species in the DCA diagram, because the station points did not show a pattern of increasing altitude along the first axis, station 2-6 showing approximately the same coordination scores. The length of the axis is expressed in multiples of the standard deviation and sites that differ four standard deviations in scores can be expected to have no species in common (Ter Braak 1995). The length of the first axis is estimated to 2.976 s.d, so theoretically all stations could have the same species, indicating that the altitudinal range in this study may be too short to detect an altitude gradient. Jacobsen (2004) pointed out that clear relationships with altitude cannot be expected to emerge from studies of narrow altitudinal ranges (<500 m). However, linear regression showed a decrease in number of species with increasing altitude, although only moderately significant ($r^2 = 0.73$, $p = 0.029$).

Several species are at the edge of the diagram. Such species have little influence on the analysis, lying there because they have few records (Ter Braak 1995). However, species at the edge of the diagram can also be rare because they prefer particular environmental conditions or habitats. This may be the case for *P. flavomaculatus, S. lacustris, I. grammatica, L. marginata* and *T. nebulosa*, recorded only in the outlet of Øvre Heimdalsvatn.

In the DCA diagram station 1 and station 6 formed two separate groups, while station 2, 3, 4 and 5 tended to form a single group together. This indicates change in species composition from the inlet of Brurskardtjern to Brurskardbekken and further a change in species composition from Brurskardbekken and to the outlet of Øvre Heimdalsvatn. Natural lakes cause a shift in the stream ecosystem structure and function (Aagaard et al. 2004). This may be an explanation for the differences in species composition from inlet streams and outlet streams in this study.

5.4. Canonical Correspondence Analysis (CCA)

In this study discharge, substrate and temperature had the longest axes in the CCA analysis, indicating that they are the major factors explaining the pattern of variation in species composition (Ter Braak 1995) detected in this study. Previous studies have shown that temperature is an important variable influencing the distribution of aquatic organisms (Brittain 1983; Füreder 1999; Füreder et al. 2005; Milner & Petts 1994; Solem 1985; Ward 1985). The role of temperature was also confirmed in the present study in Øvre Heimdalen. Both mean and minimum temperatures were important, especially in relation with distribution of invertebrates in July.

The percentage amount of particular organic matter and levels of chlorophyll *a* showed intermediate correlations in the ordination analyses, indicating some influence in the explanation of species distribution. Distribution of aquatic insects in relation to vegetation belts and allochthonous inputs has in previous studies clearly seemed to be linked to the availability of food (Cummins et al. 1973; Lillehammer 1974), but this does not seem to have a crucial role in explaining the difference in distribution of species in this study.

Depth, current velocity and the Pfankuch index, which is related to channel stability and structure, had the shortest axis in the ordination diagram, and have therefore little relationship to the pattern of variation in species compositions shown in the ordination analysis (Ter Braak 1995). Channel stability was important in determining the faunal communities in two glacial rivers (Brittain et al. 2001), but the measured values in this study showed only small differences between the reaches investigated, thus providing little explanation for the species distribution derived from ordination analyses.

From the CCA ordination diagram it can be seen that discharge and substrate size are strongly correlated with axis 1. The species *I. grammatica, L. marginata, T. nebulosa, P. flavomaculatus, Oxyethira sp., Hydroptila sp. and S. lacustris* all have a high positive score on that axis and are expected to be almost restricted to sites with high discharge and large substrate. Species with intermediate scores are either unaffected by these environmental variables or restricted to intermediate values of the environmental variables (Ter Braak 1995), which is the case for most species in this ordination.

Both minimum and mean temperatures were strongly negatively correlated with axis 2. There were no species with high negative scores on this axis, but *Nemoura pictetii* and *Capnia bifrons* have high positive score on this axis, indicating that they are almost restricted to sites with low temperatures.

Concluding comments

The environmental variables used in the CCA ordination clearly separated the outlet of Øvre Heimdalsvatn from the other stream sites situated in Brurskardbekken and the inlet stream of Brurskardtjern. Lake outlets have different habitat conditions compared to other streams (Richardson & Macay 1991), because lakes cause a shift in the stream ecosystem (Aagaard et al. 2004). This is also recorded to be the case in Alpine areas (Hieber et al. 2002). This indicates that the environmental conditions in the outlet of Øvre Heimdalen, causes a different habitat for the invertebrates compared within the streams. Several of the measured environmental variables in this study showed higher values at station 1, e.g., discharge, temperature and substrate size. This indicates that the difference in stream invertebrate fauna between alpine streams and lake outlets is the main explanation for the results in this study.

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Appendix 1

Table 1: Invertebrate data sampled in June, July and September 2009. Abbreviations are used in DCA and CCA diagrams.

Taxa and species	Abbreviation	Station 1			Station 2			Station 3			Station 4			Station 5			Station 6		
		st1jun	st1jul	st1sept	st2jun	st2jul	st2sept	st3jun	st3jul	st3sept	st4jun	st4jul	st4sept	st5jun	st5jul	st5sept	st6jun	st6jul	st6sept
TRICHOPTERA																			
HYDROPTILIDAE																			
Hydroptila sp.	hyd sp.			21												4			
Oxyethira sp.	oxy sp.	1		157									1						
LIMNEPHILIDAE																			
Apatania sp.	apa sp.						10			1								1	61
PHILOPOTAMIDAE																			
Philopotamus montanus (Donovan, 1813)	phi mon				2	4	4			8									
POLYCENTROPODIDAE																			
Plectronemia conspersa (Curtis, 1834)	ple con					1	3	2	9	9	9	15	19	1	26	11			
Polycentopus flavomaculatus (Pictet, 1834)	pol fla	211	160	218															
RHYACOPHILIDAE																			
Rhyacophila nubila (Zetterstedt, 1840)	rhy nub	1	5	4	2	4	4	4	6		10	11	3	11	4	6			
EPHEMEROPTERA																			
BAETIDAE																			
Acentrella lapponicus (Bengtsson, 1912)	ace lap					69			8			1							
Bäetis fuscatus (Linnaeus, 1761)	bäe fus		41				1					2							
Bäetis rhodani (Pictet, 1843-45)	bäe rho	16		60	40	31	104	63	60	61	24	20	16	40	66	88		89	140
Bäetis subalpinus Bengtsson, 1917	bäe sub				5		1		1	4	7	1			4				
EPHEMERELLIDAE																			
Ephemerella aroni (Bengtsson, 1908)	eph aur				1														
LEPTOPHLEBIIDAE																			
Leptophlebia marginata (Linnaeus, 1767)	lep mar			15															
SIPHLONURIDAE																			
Ameletus inopinatus Eaton, 1887	ame ino				6		4	3			15	2	10	6		1			
Siphlonurus lacustris Eaton, 1870	sip lac	1																	

Table 1 continues:

Taxa and species	Abbreviation	Station 1			Station 2			Station 3			Station 4			Station 5			Station 6		
		st1jun	st1jul	st1sept	st2jun	st2jul	st2sept	st3jun	st3jul	st3sept	st4jun	st4jul	st4sept	st5jun	st5jul	st5sept	st6jun	st6jul	st6sept
PLECOPTERA																			
CAPNIIDAE																			
Capnia bifrons (Newman, 1839)	cap bif													1					
LEUCTRIDAE																			
Leuctra digitata Kempny, 1899	leu dig				15	14	4	1	5			16	1						
Leuctra fusca (Linné, 1758)	leu fus		14	1		1													
Leuctra hippopus Kempny, 1899	leu hip			17	3			1			20			32					
Leuctra nigra (Olivier, 1811)	leu nig						7			1	1		5						
NEMOURIDAE																			
Amphinemura standfussi (Ris, 1902)	amp sta			1		21			27			25			1			3	
Amphinemura sullicollis (Stephens, 1836)	amp sul			15										14					
Nemoura cinerea (Retzius, 1783)	nem cin			2	7	1	1	14	1	1				6			43	41	53
Nemoura avicularis Morton, 1894	nem avi						1	2											
Nemurella pictetii Klapálek, 1900	nem pic																		11
Protonemura meyeri (Pictet, 1841)	pro mey				7	4	4	5	2	3	3		1	8					
PERLODIDAE																			
Diura nanseni (Kempny, 1900)	diu nan						5		6	12	11	5	16	3	9	10			
Isoperla obscura (Zetterstedt, 1840)	iso obs	1												1			3		1
Isoperla grammatica (Poda, 1761)	iso gra			21															
TAENIOPTERYGIDAE																			
Brachyptera risi (Morton, 1896)	bra ris				8		33	2		2							1		1
Taeniopteryx nebulosa (Linné, 1758)	tae neb			24															

Appendix 2

Table 1: Environmental variables measured in June, July and September 2009. Abbreviations are used in the CCA diagrams.

Environmental variables	Abbreviations	Station 1			Station 2			Station 3			Station 4			Station 5			Station 6		
		st1jun	st1jul	st1sept	st2jun	st2jul	st2sept	st3jun	st3jul	st3sept	st4jun	st4jul	st4sept	st5jun	st5jul	st5sept	st6jun	st6jul	st6sept
Discharge l/s	DISCHARGE	260	50	610	66,24	24,95	22,39	12,06	9,51	4,00	16,71	4,67	3,17	11,06	-	7,31	4,21	3,18	2,89
per cent organic material in kick samples	ORG.MAT	35,9	48,6	34,13	11,99	31,8	13,28	11,61	27	9,87	23,42	32,1	29,82	26,68	38	31,04	26,3	46,9	32,53
Chlorophyll *a* mg/m²	CHL *a*	1,945	4,47	3,74	0,25	0,52	0,65	0,2	0,97	1,48	2,7	0,56	1,9	3,7	0,57	10,63	4,08	0,7	0,68
Depth at time of survey cm	DEPTH	32	28	17	28	17	16	14	19	21	18	22	32	28	17	19	16	13	16
Current velocity m/s	VELOCITY	0,47	0,19	0,23	0,51	0,63	0,43	0,17	0,63	0,24	0,26	0,15	0,07	0,22	0,19	0,27	0,31	0,33	0,17
Pfankuch index	PFANKUCH	32	32	32	37	37	37	26	26	26	24	24	24	19	19	19	26	26	26
Temperature minimum °C	MIN. TEMP	5,18	11,5	7,58	0,61	5,64	3,59	0,21	7,72	4,7	0,33	7,88	4,83	0,78	9,45	5,56	0,01	3,93	2,23
Temperature mean °C	MEAN TEMP	9,83	11,8	10,31	5,33	9,99	7,59	5,97	8,82	8,01	5,75	11,7	8,01	4,51	12,4	8,35	2,5	8,14	5,75
Average B-axis stone length cm	B-AXIS	6,24	6,24	6,24	4,69	4,69	4,69	5,17	5,17	5,17	5,71	5,71	5,71	5,18	5,18	5,18	5,3	5,3	5,3
Precentage amount of boulders	% BOULDERS	30	30	30	5	5	5	25	25	25	10	10	10	25	25	25	10	10	10